Crater wall and rim material, undivided—Hummocky material consisting

Satellitic crater material—Small, bright, sharp-rimmed, circular to elon-

Material of small craters—Craters are less than 10 km in rim-crest

formed by fragments ejected from Ottumwa and Jeki

Hesperian materials interpreted to have formed between floods

[Subscripts apply to this map area only]

levels marked by grooved channel material (unit Hch)

Hesperian materials whose age relative to floods is unknown

blankets than Amazonian craters of similar size

Hesperian materials interpreted to have predated early flood

[Subscripts apply to this map area only]

Hcw₁ Crater wall material—Similar to wall material in other Hesperian craters

Crater material, undivided—May include floor, wall, and rim materials of

moderately subdued craters having less relief and narrower ejecta

but impacted in places by satellitic (secondary) craters from Sharonov

Hcp₂ Crater peak material

Crater wall material

cp Crater peak material

low Crater wall material

Hcp₁ Crater peak material

Crater rim material, lobate

Crater rim material

ejecta deposits of bedrock and breccia

PLAINS AND PLATEAU MATERIALS

Ridged plains material—Forms broad, planar surface of Lunae Planum;

has relatively low albedo and subparallel systems of mare-type wrinkle

ridges. Light and dark layers visible in some canyon walls. Interpreta-

tion: Probably lava flows of basaltic composition; ridges may be dikes

intruded during crustal extension or folds formed by compression;

moderate to low relief and relatively low albedo. Craters moderately

to highly degraded. Embays Noachian subdued cratered plateau

material but appears transitional with ridged plains and smoothed

surficial materials probably formed by sheetflooding and minor

surface of low relief; rounded or smoothed texture. Interpretation:

moderate relief. Unit appears to embay knobs and ridges of hilly

plateau material and is overlain by ridged plains lava flows and

smoothed cratered plateau material. Interpretation: Remnant of

highland surface consisting of interbedded lava flows, impact breccias,

central part of map area; similar to subdued cratered plateau material

but more rugged and has greater relief. Interpretation: Ancient

volcanic rocks and breccias considered to be part of basement

channeling of ridged plains lava flows and possibly older rocks

Smoothed cratered plateau material—Has relatively featureless, uneven

Sheetflood deposits of thinly reworked surficial materials

Subdued cratered plateau material—Surface is cratered, uneven, of

cratered plateau materials. Interpretation: Thin layer of reworked

layering suggests weathered zones or variations in composition

Dissected plateau material—Forms furrowed or gullied upland terrain of

DESCRIPTION OF MAP UNITS

[Map-unit symbol in parentheses on map denotes buried unit]

CHANNEL MATERIALS

mantle of fluvial and eolian material

scour marks on channel floor

Channel material, smooth—Forms smooth, lower-level floor of Kasei

Valles; lacks longitudinal grooves, scour marks, and terraces; wrinkle

ridges visible in places. Embays or transects some sharp-rimmed

craters (unit Hc₂) and grooved channel material (unit Hch); super-

pretation: Fills channel eroded by last catastrophic flood in Kasei

Valles; some Hesperian craters (unit Hc₂) document occurrence of

separate flood events. (For examples, see fig. 4B). Unit probably a thin

Valles; extends above smooth channel material. Floor markings

parallel channel course but locally show transectional cross patterns.

older Hesperian craters (unit Hc₁) deeply grooved. Crater counts

indicate age as old as Early Hesperian (see text). Interpretation:

grooved channel material; embays remnant islands of ridged plains

material; faint striations visible in places. Interpretation: Flood-plain

material indicating high-water overflows from main channels of early

hills in depressions; also found on walls and floors of grabens and at

base of Lunae Planum plateau escarpment. Interpretation: Formed

by collapse and disruption of canyon walls following release of ground

Chaotic material—Forms irregular knobs, mounds, and small, flat-topped Nplh Hilly plateau material—Forms hills and low massifs mostly in south-

Channel plains material—Forms smooth, low-lying plains adjacent t

Channels eroded by early stages of flood episodes indicated by two

erosional classes of crater materials and suggested by transecting

Some sharp-rimmed Hesperian craters (unit Hc2) unmarked, but

Channel material, grooved—Forms striated and terraced floor of Kasei

posed by Amazonian craters and secondary craters from crater

Ottumwa. Crater counts indicate Amazonian age (see text). Inter-

of kilometer-size blocks and hills on walls and rim of crater Ottumwa;

gradational with lobate rim material. Interpretation: Thick, unsorted

(Acso) and to crater Jeki (Acsj). Interpretation: Secondary craters

diameter, have sharp to moderately subdued rim crests and narrow

channel material (unit AHch). Craters lie below early flood-stage

ejecta blankets; most craters embayed or transected by younger

gate craters in chains and clusters mostly radial to crater Ottumwa

Fault or graben—Dashed where approximately located; dotted where

buried. Bar and ball on downthrown side of fault

Scarp marking base of Lunae Planum plateau—Dashed where buried

highland and lowland physiographic provinces

by crater ejecta

Terrace—Mapped on channel walls

in ridged plains material

— . — . — Small channel—Residual post-flood drainage

Direction of channel flow

Buried crater rim crest

Smooth plains material

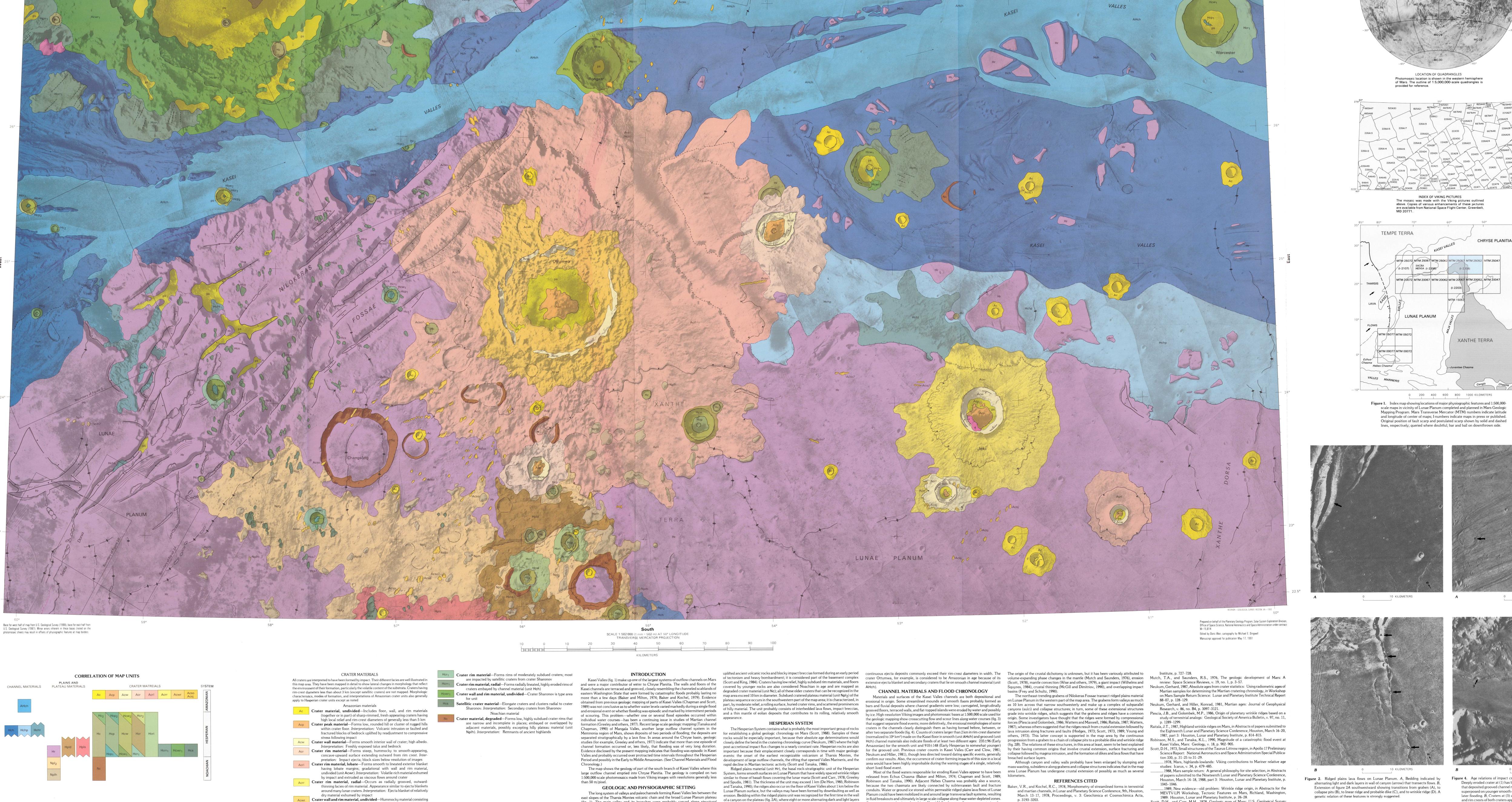
Crater rim crest

Crater central pit

s Slide material

Depression—Probably formed by collapse

── Wrinkle ridge—Mare type, largely restricted to ridged plains material



(fig. 1). The main valley and its branches were probably carved along structural

discontinuities by catastrophic flooding during the Hesperian Period. (See Structure.)

he valley system extends about 2,400 km from a possible source area in Echus Chasma

catchment basin of flood waters from Kasei Valles and other channels in the region. The

long, the gradient exceeds 13 m/km (U.S. Geological Survey, 1989). The valley system

from the extensive melting of ground ice followed by rapid draining and subsurface

collapse. (See Channel Materials and Flood Chronology.) The valley system broadens

and divides (fig. 1) into two large branches that extend eastward across Lunae Planum

and the highland-lowland boundary scarp; elsewhere on Mars this scarp separates older,

cratered, upland terrains from younger, smoother, less cratered lowland plains. In the

older rocks on Lunae Planum and have streamed across the boundary scarp onto the

The Martian time-stratigraphic systems were formally named and defined on the

global geologic map of Mars at 1:25,000,000 scale (Scott and Carr, 1978) that was made

using Mariner 9 images. The relative ages of major rock units in the map area were

previously established (Scott and Tanaka, 1986) on the geologic map of the western

equatorial region of Mars at 1:15,000,000 scale based on Viking images. Minor

resolution imagery and larger scale portrayal used in the present mapping. Channel wall

and floor materials are assigned ages that reflect their time of formation and modification

by water action rather than the original time of emplacement of their component rock

lava flows of Hesperian age that cover Lunae Planum. Hilly plateau material (unit NpIh) of

Early Noachian age at the base of the plateau sequence is exposed mostly in Xanthe

cuts Lower Hesperian rocks but is partly covered in places by Middle Amazonian lava

overall gradient of Kasei Valles is about 3 m/km, but in their upper part, some 600 km

Contact—Dashed where approximately located; queried where uncertain (Chapman and Scott, 1989) to the lowland plains in Chryse Planitia, the former

Lobate scarp—Marks base of lobate flows of crater ejecta; barb points flows from Tharsis Montes (Scott and Tanaka, 1986). Floodwater probably originated

Layer in canyon wall—Layers occur as alternating light and dark streaks map area, however, lava flows of intermediate age (Early Hesperian) have mostly buried

Highland-lowland boundary scarp—Diffuse zone of transition between modifications of some units and their contacts have been made as a result of the higher

materials (Milton, 1974).

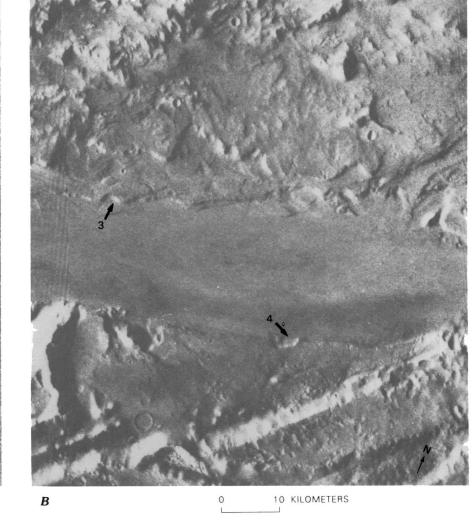
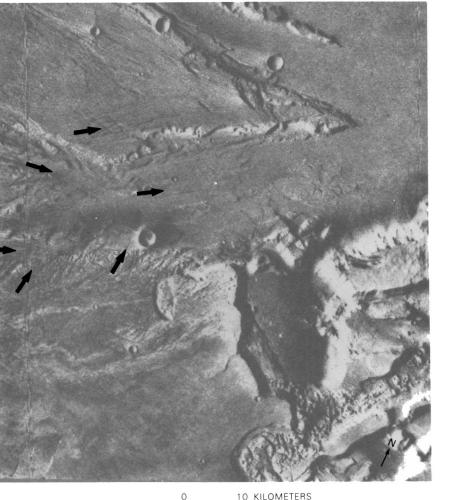


Figure 4. Age relations of impact craters to two separate floods in Kasei Valles. A, Deeply eroded crater at (1) has been almost obliterated by early, high-water flood that deposited grooved channel material (unit Hch); fresh-appearing crater at (2) is superposed on younger smooth channel material (unit AHch) and is unmarked by later flooding. B, Craters at (3) and (4) formed between these two floods. Floors and rim crests of both craters appear to be uneroded by early, high-water flood but have been cut in two by later, low-water flood.



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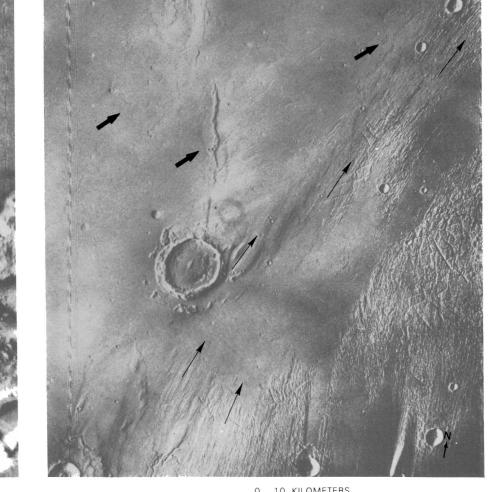
scarp appears to have acted as a dam against which the Tharsis lava flows were checked J.A., 1977, Geology of Chryse Planitia: Journal of Geophysical Research, v. 82,

broadly indicated by symbol. This boundary represents a crustal dichotomy of global Milton, D.J., 1974, Geologic map of the Lunae Palus quadrangle of Mars: U.S.

extent and is marked in many places by a scarp between old, highly cratered highlands Geological Survey Miscellaneous Investigations Series Map I–894, scale 1:5,000,000.

geologic provinces on Mars roughly extends through the center of the map area and is Research, v. 95, no. B8, p. 12,595–12,605.

Figure 3. Channel crosscut by scour lines (arrows), which suggests that flooding was Figure 5. Kasei Valles floor (southeast half of image) and Tharsis Montes Formation



(northwest half). Grooves and streamlines on channel floor show directions of water flow (narrow arrows). These directions suggest component of flooding from flanks of Tharsis Montes. Lava-flow directions (wide arrows) indicated by lobate fronts. Image centered at about lat 18° N., long 78°

thick (if the canyon is assumed to be nearly 1 km deep).

and dissected to different degrees by sheetfloods and channels.

Generally, Hesperian craters have less extensive (less than one rim-crest diameter)

ejecta blankets than Amazonian craters of comparable size, and their fields of secondary

AHch). As a group they probably range in age from mid-Hesperian to Early Amazonian:

AMAZONIAN SYSTEM

above younger materials. Other than relatively prominent relief, the unit lacks observable AHch), no units of Amazonian age have been recognized in the map area. Impact craters covered by crater materials and by ridged plains lava flows that have streamed across the

primary characteristics that might indicate its mode of origin. It is interpreted to consist of are assigned relative ages based on superposition relations and morphology. Their escarpment, and only scattered exposures of highland rocks occur along the boundary.

GEOLOGIC MAP OF THE MTM 25057 AND 25052 QUADRANGLES, KASEI VALLES REGION OF MARS

The Noachian System consists of the oldest rocks on Mars, most of which occur in they are discussed, together with their origin, in Channel Materials and Flood map area.

1986). Noachian exposures in the map area are sparse, because they are largely buried by formed throughout the Hesperian and Amazonian Periods.

Materials occurring in outflow channels and on flood plains exhibit both depositional and deposited.

occur. The layers appear to have about equal thicknesses; each is probably about 100 m Some water was also introduced into Kasei Valles from smaller canyons entering the

small channels, they are classified as dissected plateau material (unit HpId). Smoother flanks of Tharsis Montes. These Amazonian lavas partly cover Upper Hesperian flows

napped as smoothed cratered plateau material (unit HpIs). Both of these units are better suggested by scour marks directed in places toward a more western source than the

interpreted to consist of thin layers of reworked surficial materials that have been eroded of similar appearance are common on basalt surfaces in the channeled scablands of the

more readily mappable than those of Noachian age. However, Hesperian craters are their existence supports the concept that some flood waters of Kasei Valles may have

craters are less well developed or not recognizable. However, the large (100-km rim-crest

The north-trending course of Kasei Valles (fig. 1) extending from Echus Chasma to

diameter) Hesperian crater Sharonov has many fresh-appearing secondaries, some of about lat 25° N., where it branches and turns eastward, may follow a large fault scarp. The

stratigraphic relations: it is superposed on Hesperian ridged plains material, but its rim erosional feature (fault-line scarp) that has retreated several kilometers eastward from

Amazonian-Hesperian in age). Other Hesperian craters are assigned relative ages if their is less conjectural, because it is clearly marked by a major disconformity for several

the southern highland region where they form the plateau sequence (Scott and Tanaka, Chronology. Smooth plains material (symbol s) probably and slide deposits (symbol s) prob

Terra, where it forms a rough terrain of irregular hills and individual peaks that project With the exception of crater materials and, possibly, smooth channel material (unit and relatively young, less cratered plains. In the map area, the boundary is mostly Mouginis-Mark, Peter, 1989, Recent water release in the Tharsis region of Mars, in

bearing the subscript "1" indicate craters formed prior to flooding; those with the discontinuity separates ridged plains material of Early Hesperian age on the east from the and Space Physics, v. 19, p. 13-41.

materials are dissected by channels of at least two flood stages (Hesperian and the original fault trace. The continuation and northwest extension of this postulated fault

more difficult to distinguish from Amazonian craters on the basis of morphology alone. originated from late-stage volcanism at Tharsis Montes.

Hesperian impact craters can be identified by superposition relations and mor-flood-flow streamlines (Baker and Kochel, 1978). Elsewhere in the Tharsis region, young

main channel. Another, as yet unexplored, water source may have been ground-ice

terrains having moderate to low relief and less conspicuous drainage channels are that may have been responsible for initiating later flood stages in Kasei Valles, as Carr, M.H., and Clow, G.D., 1981, Martian channels and valleys: Their characteristics,

developed in the adjacent map area to the south (De Hon, 1992), where they have been main southern course of the Kasei channel (fig. 5). Scour marks and longitudinal grooves

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Columbia Basin in Washington State, where they are aligned parallel to prevailing

phology: they have a relatively fresh appearance, prominent rims, and ejecta blankets channels of probable fluvial origin occur in Amazonian lava flows (Mouginis-Mark, 1989);

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which are found beyond the map area. Sharonov's relative age is readily determined by canyon wall now separating Lunae Planum plateau from the valley floor is probably an Frey, H.V., and Schultz, R.A., 1990, MEVTV study: Early tectonic evolution of Mars—

positions in sequence can be determined with respect to major flood events. (Symbols hundred kilometers (to about lat 30° N., long 82°); this stratigraphic and structural Greeley, Ronald, and Spudis, P.D., 1981, Volcanism on Mars: Reviews of Geophysics

subscript "2," craters formed between floods.) No Hesperian craters are assigned to a Tharsis Montes lava flows of Late Hesperian age on the west. Here the west-facing fault Greeley, Ronald, Theilig, Eileen, Guest, J.E., Carr, M.H., Masursky, Harold, and Cutts,

and erosional features. They include grooved channel material (unit Hch), channel plains

The branching and eastward diversion of Kasei Valles across Lunae Planum may be

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material (unit Hchp), chaotic material (unit Hcht), and smooth channel material (unit attributed to flood-water erosion along topographic lows formed by grabens radial to Report: National Aeronautics and Space Administration Special Publication 330,

Where ridged plains or possibly older materials have been furrowed and gullied by reservoirs within older, brecciated terrain underlying extensive lava flows on the east Baker, V.R., and Milton, D.J., 1974, Erosion by catastrophic floods on Mars and